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AGRICULTURAL EXPERIMENT STATION DEPARTMENT

G. T. WINSTON, LL.D., DIRECTOR

The Digestibility of Some Non-Nitrogenous Constituents of Certain Feeding Stuffs.

THE PURIFICATION OF PHLOROGLUCINOL.

G. S. FRAPS.

UNDER THE DIRECTION OF W. A. WITHERS, CHEMIST.

WEST RALEIGH, N. C.

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THE NORTH CAROLINA COLLEGE OF AGRICULTURE AND MECHANIC ARTS

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The Station is glad to receive any inquiries on agricultural subjects. *Address all communications to the Agricultural Experiment Station, and not to individuals.* They will be referred to the members of the Station staff most competent to answer them.

LETTER OF TRANSMITTAL.

N. C. College of Agriculture and Mechanic Arts,
Agricultural Experiment Station Department,
Division of Chemistry, Raleigh, N. C.

Sir:—The problem of animal nutrition lies at the foundation of the economic production of animals, which is one of the grand divisions of the work on the farm. Any information as to the effects of feeding stuffs on the animal body or in regard to the changes which are brought about in the feeding stuff by the animal body, will prove useful to the practical stockman, ultimately if not immediately. The observant feeder does not need to be told that by varying the relation between the amounts of concentrates and roughage, there will be a difference in the flow of milk and the amount of butter produced. Only a little thought will convince him that it is the difference in composition of the feeding stuff, which brings about such different results. For this information he must consult the chemist. The chemist has come to the aid of the stockman, and has made many analyses of the feeding stuffs and excrements, and upon the basis of these results has formulated standards for feeding animals, to produce the greatest results with the least expenditure. The value of this work is abundantly shown by the experience of the practical stockman who has adopted these standards. These standards and the analysis of our usual feeding stuffs may be found in Bulletin No. 163 of this Experiment Station.

These calculations are based upon the percentage and total amount of protein, carbohydrates, and fats digested. Additional investigations have been made showing the units of heat in the feed which have been utilized in the animal body, and still other determinations have shown the amounts of carbon, hydrogen and nitrogen which have been utilized by the body. A few experiments have been made in which there was a study of the digestibility of the sugars, some have studied the reducing sugars, others starch, and still others the digestibility of the pentosans. No previous experiments have been performed in which there was a study of the digestibility of all these constituents in the same feeding material. This Division has begun the study of the digestibility of the proximate constituents or groups of proxi-

mate constituents of feeding stuffs, and hopes to continue the work when additional material becomes available.

To Dr. Fraps, Assistant Chemist, was assigned the determination of the digestibility of the sugars, total pentosans and the pentosans in crude fiber in timothy hay, green rape and in crabgrass hay alone, and with cowpea meal, corn bran, and rice bran, which materials were left over from the experiments which are published in Bulletins 148 and 160, or in manuscript awaiting publication. From these determinations and the determination of the digestibility of starch by Sherman, he has calculated the digestibility of some other non-nitrogenous constituents, and has found that the order of digestibility is sugars, starch, pentosans, crude fiber, residual nitrogen-free extract, and pentosans in the crude fiber—the sugars and starches being practically entirely digested.

To the practical stockman these results emphasize the great value of the feeding stuffs containing large amounts of the sugars and the starches. To the student of animal nutrition they suggest the importance of determining the sugars, starches and pentosans in feeding experiments, possibly even at the sacrifice of the crude fiber determination.

Very respectfully,

W. A. Withers,
Chemist.

To Dr. Geo. T. Winston,
Director.

The Digestibility of Some Non-nitrogenous Constituents of Certain Feeding-stuffs.

G. S. FRAPS, PH.D., Assistant Chemist.

INTRODUCTION.

As is well known, the ether-extract, protein, nitrogen-free extract, and crude fiber determined in feeding-stuff analyses, are composed of various substances with different coefficients of digestibility. The ether-extract contains, besides the true fats, waxes, cholesterin, phytosterin, lecithin, hydrocarbons, coloring materials, etc. The "protein" includes proteids of varied nature, amido compounds, acid amides, organic bases, ammonia, nitrates, and other compounds which have not been studied. One of the proteids, nuclein, is entirely indigestible. The nitrogen-free extract may contain sugars, dextrines, gums, starches, pentosans, coloring matters, organic acids, so-called hemicelluloses, lignocellulose and cellulose, the two latter, as is well known, being partly dissolved by the $1\frac{1}{4}$ per cent acid or alkali. The crude fiber contains the true cellulose and the lignocelluloses which have not been dissolved by the alkali and acid.

These compounds vary in digestibility and in their usefulness to the animal body. Some possess a high coefficient of digestibility, some a low one; the digestibility of the fodder groups depends on the nature of the compounds of which they are composed.

In the work about to be described, determinations have been made of the digestibility of certain of the constituents of the nitrogen-free extract and the crude fiber. The sugars, total pentosans, and pentosans in the crude fiber, have been determined in the food and excrement from certain digestion experiments. These determinations give a basis for calculating the digestibility of the following groups: (1) sugars; (2) pentosans in nitrogen-free extract; (3) pentosans in crude fiber; (4) pentosan-free crude fiber; (5) residual nitrogen-free extract, i. e., total nitrogen-free extract less sugars and pentosans contained in it. Starch should also have been determined, but it was not undertaken.

The materials used in this work are feeding stuffs, wastes, and excrements from one digestion experiment on sheep described in Bul-

letin 148 of this Station, all described in Bulletin 160, and also one on timothy hay not yet published.

SUGARS.

All feeding stuffs contain sugars to a greater or less extent. As the sugars are generally digested completely, to subtract them from the nitrogen-free extract will lower its coefficient of digestibility.

Determinations have been made in this country on the digestibility of sugars. W. H. Jordan, J. M. Bartlett and L. H. Merrill, at the Maine Experiment Station (*a*), found that the sucrose and glucose of alsike clover, white clover, bluejoint, orchard grass, red top, timothy, wild oat grass, witch grass, buttercup, and white weed, are completely digested. E. F. Ladd, at the New York (Geneva) Experiment Station (*b*), found the sucrose and glucose to be completely digested in alfafa hay, mixed hay, wheat bran, corn meal, cotton-seed meal, linseed meal and oats; in an experiment in which turnips and mixed hay were fed, the glucose was completely digested, but the sucrose was digested to the extent of only 78.7 per cent, the excrement containing 1.20 per cent of sucrose. The writer has been unable to find an explanation for this anomalous result; true Hofmeister (*c*) has found a limit to the assimilation of sugar by dogs, the limit being 10 grains of cane sugar or 5 grains of dextrose by dogs weighing from 2.5 to 3.6 helogrammes. There may also be a limit for herbivorous animals, but the weight of sugar fed in the case above noted was exceeded in three of the other five rations, so this can not be the explanation.

At the North Carolina Station,B. W. Kilgore and F. E. Emery (*d*) found the reducing sugars digested 100 per cent in corn fodder, crimson clover hay, cowpea-vine hay, soja-bean silage, cotton seed, and cotton-seed hulls. The water-soluble polysaccharides were not determined. H. C. Sherman (*e*) found the soluble carbohydrates of wheat bran digested 96.9 per cent, the faeces containing 0.7 per cent. This is another exceptional case.

DIGESTIBILITY OF SUGARS.

A number of excrements from digestion experiments made at this station were examined to see if any exceptional case could be found in which the sugars were not completely digested. Those excrements were selected which it was thought would most probably be exceptional.

In many cases, a slight reduction of Fehling's solution occurred. The following method of examination was adopted: Three grams

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a Report: 1888, 98; Agricultural Science: *2*, 300. *b* Report for 1889, 149. *c* Experiment Station Record: *11*, 461. *d* Technical Bulletin No. 4. *e* Jour. Am. Chem. Soc.: *19*, 291; Analyst: *22*, 270.

excrement was stirred with 50 cc water for one hour, filtered, and washed to a volume of nearly 200 cc. Direct treatment of this solution with the copper reagent was unsatisfactory, a blue compound insoluble in water separating usually; so basic lead acetate was added to the solution, it was made up to 200 cc., shaken and filtered. To 50 cc. of the filtrate, heated to boiling, 10 cc. of the mixed allihn reagent was added, the solution boiled and filtered as usual. For sucrose, the filtrate was inverted, etc., in the usual way.

With some of the excrements, no visible reduction of copper occurred; with the others the reduction was always very slight, the cuprous oxide only visible after the solution had been filtered and the filter washed. The precipitate could not be weighed, being at the greatest 3 mgr., so it was dissolved in nitric acid, and determined colorimetrically with potassium ferrocyanide.

The following excrements contained no sugars, and therefore, the sugars in the corresponding feeding stuffs were digested 100 per cent; 758, from crabgrass hay; 762, from crabgrass hay and pea meal; 815, from crabgrass hay and corn bran; 910 and 911, from green rape; 915, from crabgrass hay and rice bran; 1431, 1432, from cattail millet; 1433, from sorghum fodder; 1434, from crimson clover hay; 1436, from soja-bean silage.

The following excrements reduced traces of copper, corresponding to the percentage of sugars:

No.	Origin.	Reducing Sugars.	Sucrose.
763	Crabgrass hay and pea meal	0	0.06
815	Crabgrass hay and corn bran	0	0.16
913	Green rape	0 05	0.04
914	Crabgrass hay and rice bran	0	0.06
1348	Corn silage	0	0 04
1349	Corn silage	(with sucrose)	0.14
1376	Corn silage	" "	0.15
1377	Corn silage	" "	0 05
1410	Timothy hay	" "	0.06
1411	Timothy hay	" "	0.20
1435	Corn fodder	0.06	0.08
1437	Sorghum fodder	0.05	0.09

The reduction above noted may have been due to other bodies than sugars. Experiments were made to test this point. Four excrements were selected, namely: 1376 and 1377, from corn silage; 1411, from timothy hay; and 1437, from sorghum fodder.

Fifty grams of each were digested with 500 cc. cold water, filtered through linen, and washed with about 1,000 cc. water. Basic lead

acetate was then added in excess, the precipitate filtered off and washed. The filtrate was evaporated to about 25 cc., organic matter separating during the process. The lead was removed with sodium carbonate, the solution filtered, and washed to 100 cc. 25 cc., corresponding to 12.5 grams excrement, about 17 times as much as was used before, was allihned; another 25 cc. inverted with hydrochloric acid and allihned. In no case was there the slightest reduction of copper, showing the absence of sugar. We may safely conclude that the traces of copper oxide formed in the preceding experiments were due to bodies not sugar.

The following statements appear justified:

(1) Sugars in the ordinary feeding stuffs may be regarded as digested completely.

(2) Traces of reducing substances are sometimes present in excrements, but are probably not sugars.

DIGESTIBILITY OF NITROGEN-FREE EXTRACT LESS SUGARS.

A comparison between the digestibility of the entire nitrogen-free extract, and that of the nitrogen-free extract less the sugars, shows at times a considerable difference, as might be expected in the case of materials containing much sugar and a nitrogen-free extract with a low coefficient of digestibility.

A comparison is made in Table I; it is partly worked out from the

TABLE I.—*Digestibility of Nitrogen-free Extract Less Sugars.*

	(a) N-free Extract.	Ditto, less Sugars.	a—b.
New York Station:			
Alfalfa hay	71 8	68 5	3.3
Mixed hay	55 5	40.4	15.1
Mixed hay and turnips	61 4	49 2	12.2
Mixed hay, corn meal, cotton-seed meal and wheat bran	77.4	73 9	3.5
Mixed hay, corn meal, wheat bran	83.5	81.6	1.9
Mixed hay, corn meal, wheat bran, cotton-seed meal, linseed meal, oats	67.4	60.6	6.8
North Carolina Station:			
Timothy hay No. I	60 3	53 5	6.8
Green rape No. I	93 8	92 5	1.3
Green rape No. II	89 9	87.9	2.0
Crabgrass hay No. I	49 7	47.5	2 2
Crabgrass hay No. II and pea meal	76 6	74 8	1.8
Pea meal	95 4	95 0	0.4
Crabgrass hay No. I and corn bran	74 6	73 5	1.1
Corn bran	80 3	79.5	0 8
Crabgrass hay No. II and rice bran	65 9	64.6	1.3
Rice bran	80 4	79.9	0.5
Timothy hay No. II	56.2	51.1	5.1

digestion experiments made at the New York Station (Table II), already cited (Report 1889), and partly from digestion experiments made at this Station, the determination of sugar being made for this purpose, by the methods of the O. A. A. C. (Tables X-XVI).

The decrease in the digestibility of the nitrogen-free extract when the sugar is subtracted, is often considerable in the case of the fodders, and appreciable, though less, in the case of concentrated feeding stuffs. With alfalfa hay, the decrease is 3.3 per cent; 15.1 per cent with mixed hay; 6.8 per cent and 5.1 per cent with timothy hay;

TABLE II.—*Digestibility of Nitrogen-free Extract less Sugars. New York (Geneva) Station.*

	Sugars.	N-free Extract.	N-free Extract less Sugars.
A.—Alfafa hay fed (in ounces)	14 20	135 56	121.36
In excrement	0	38 26	38.26
Digested	14 20	97 30	83.10
Per cent digested	100	71.8	68.5
B.—Mixed hay fed	23.02	90.91	67.89
In excrement	0	40 45	40.45
Digested	23.02	50.46	27.44
Per cent digested	100	55 5	40.4
C.—Mixed hay and turnips fed	22.62	89 18	66.56
In excrement	1 07	34.38	33.31
Digested	21.55	32.18	33.25
Per cent digested	....	61 4	49.2
D.—Mixed hay, co--rn meal, cotton-seed meal, wheat bran fed	22 23	162.72	140.49
In excrement	0	36 74	36.74
Digested	22.23	125.98	103.75
Per cent digested	100	77.4	73 9
E.—Mixed hay, corn meal, wheat bran fed	16 83	168.64	151.81
In excrement	0	27.91	27.91
Digested	16.83	140.73	123.90
Per cent digested	100	83.5	81 6
F.—Mixed hay, wheat bran, corn meal, cotton-seed meal, linseed meal, oats fed	38 01	219.08	181.07
In excrement	0	71.37	71.37
Digested	38.01	147 71	109.70
Per cent digested	100	67.4	60.6

2.2 per cent with crabgrass hay. With green rape, the decrease is 1.5 and 2 per cent; with pea meal, only 0.4 per cent; with corn bran, 0.8 per cent; with rice bran, 0.5 per cent. In the case of cotton-seed meal, the nitrogen-free extract of which, containing about 33 per cent sugar, has a digestibility of 6.15(a), to subtract sugars lowers it to about 42.5 per cent, a decrease of 19 per cent. These figures show the importance of determining sugars when digestion experiments are made with hay and fodders.

TABLE III.—*Sugar Content of Feeding Stuffs, on Dry Matter.*

No.		Reducing Sugars.	Soluble Polysaccharides as Sucrose.	N-free Extract.	Sugars ÷ N free Extract.
	New York Station:				
	Alfalfa hay	3 00	1.40	41.13	10.7
	Mixed hay	8.00	2 44	48 68	21.4
	Turnips	25.46	4.88	64.07	47.4
	Wheat bran	1.96	2.20	62.98	6.6
	Corn meal	0	2.40	78.62	3.1
	Cotton-seed meal	0	9 22	27.57	33.5
	Linseed meal	0.20	2 32	40 39	5.9
	Oats	1.20	0	71.75	1.7
	North Carolina Station:				
656	Timothy hay No. I	4.97	3 36	55 92	14.9
753	Crabgrass hay No. I	1 42	0.47	45.19	4.2
754	Crabgrass hay No. II	2.20	0	46.15	4.8
759	Cow-pea meal	0	5.66	64 63	8.7
812	Corn bran	2.21	0.72	69 46	4.2
820	Green rape No. I	5.22	1.81	42.49	15.2
819	Green rape No. II	4.27	4.14	46.41	19.8
917	Rice bran	0.97	0.59	51.75	3.0
*1412	Timothy hay No. II	2.06	3.24	50.22	10.5
*1359	Corn silage No. I	1.76	0.11	55 40	3.4
*1378	Corn silage No. II	2.27	0 12	50.66	4.7
*1414	Cotton-seed meal	0	7.94	24.1	32.9
*1418	Timothy hay No. III	4.81	3.75	53.6	16.0

* Not digested.

In Table III is tabulated the sugar content of the feeding stuffs used in the digestion experiments above mentioned, and also what percentage of the nitrogen-free extract is sugars. The hays contain usually a moderate amount of sugars—for example(b), red clover, (average of 21), contains 6.36 per cent; timothy hay (average of 21), 8.44 per cent, sorghum, 21.0 per cent, corn fodder, 3.93. Timothy sometimes contains as much as 10.73 per cent(c). Concentrated foods have a low percentage of sugars, with the exception of

a Bulletin 97, this Station. b E. F. Ladd; Am. Chem. Jour. *10*, 49. c Jordan, Bartlett & Merrill; Agr. Science *2*, 300.

cotton-seed meal, in which 9.22 and 7.94 per cent of sugar (raffinose) is contained, making up 33.5 and 32.9 per cent of the nitrogen-free extract. The great effect this high percentage of sugar has on the digestibility of the nitrogen-free extract has already been noted, nitrogen-free extract less sugar being digested 42.5 per cent, including sugar, 61.5 per cent, or nearly one-half more.

STARCH.

The determination of the digestibility of starch in the samples which were used for pentosans and sugars, was not made on account of lack of material. The writer has been able to find only one digestion experiment in which the digestibility of starch was determined, using the diastase method for solution of the starch. In this experiment,[a] with wheat bran, starch was entirely digested. A number of digestion experiments have been made in which the starch was determined by hydrolyzing it with dilute acids, but dilute acids dissolve other bodies than starch, and the figures obtained by this method can not be taken to represent the digestibility of starch. Starch probably possesses a high coefficient of digestibility. The nitrogen-free extract of many human foods, composed mainly of starch, such as flour, corn meal rise, is digested to the extent of 95 to 100 per cent; and the nitrogen-free extract of concentrated cattle foods which contain much starch possesses a high coefficient of digestion, usually above 85 per cent. Fodders and hays contain but little starch. As will be seen later, the starch in rice bran is digested at least 85 per cent, of corn bran 86 per cent, and of cowpea meal 97.4 per cent. It is more probable that the digestibility of starch is nearly 100 per cent.

PENTOSANS.

The furfural produced by distillation of feeding stuffs with hydrochloric acid, is generally ascribed to the pentosans, i. e., bodies which yield pentose sugars upon hydrolysis. The pentosans are hydrolized by dilute mineral acids to the sugars xylose and arabinose.

Other bodies than the true pentosans are found in plants which when distilled with hydrochloric acid, give rise to furfural, such as the oxycelluloses and lignocelluloses. The latter are usually described as mixtures of cellulose and non-cellulose, the non-cellulose being generally known as "encrusting matters," or "lignin." (Cross and Bevans "Cellulose," page 93.) The oxycelluloses yield from 2 to 8 per cent of furfural, the typical lignocellulose, jute, yields 9-10

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a H. C. Sherman, Jour. Am. Chem. Soc., *19*, 291.

per cent. The oxycelluloses and lignocelluloses are not true pentosans, for the reason that they are more resistant to hydrolyzing agents, and, when hydrolized, besides the pentoses other bodies are formed. We are, as yet, unable to distinguish sharply between the true pentosans, and the oxycelluloses and lignocelluloses, to which the name pseudo-pentosans may be applied. The true pentosans are presumably dissolved completely by acids and alkalies, and so are contained in the nitrogen-free extract; but the pseudo-pentosans are also partly dissolved by these reagents. The furfural from the crude fiber may be considered as originating entirely from lignocelluloses and oxycelluloses, and that from the nitrogen-free extract, while perhaps mainly from true pentosans, comes in part from pseudo-pentosans also.

DETERMINATION OF FURFURAL-PRODUCING BODIES.

Furfural-producing bodies in feeding stuffs or other materials are determined by distilling them with hydrochloric acid of 1.06 specific gravity, and determining the furfural in the distillate. Furfural has been determined by titrating with a standard solution of phenylhydrazine(*a*), using aniline acetate or Fehling's solution as an indicator, by neutralizing the solution with sodium carbonate, precipitating the furfural with phenylhydrozine, and weighing the precipitate(*b*), and by precipitating it directly with phloroglucinol(*c*), and weighing the precipitate. The volumetric method gives too high results, on account of the presence of acetone or levulinic acid (*b*); phloroglucinol as a precipitant possesses advantages over the phenylhydrazine, and is usually used.

The method used in this laboratory will here be described:

Three grams of the substance are brought into a side-neck distilling flask of about 300 cc. capacity, which is connected with a Liebig condenser, together with 100 cc. of hydrochloric acid of 1.06 specific gravity. The distillate passes through a filter paper in a small funnel into a measuring cylinder. The filter is necessary to remove fats or fatty acids, which always distil over with the furfural. Thirty cc. of fresh acid are added from a separating funnel as soon as 30 cc. have been distilled in such a manner as to wash down the particles which adhere to the sides of the flask. If the flask is placed on a wire gauze, and care taken to keep the particles washed down, there is little danger of charring on the sides of the flask. The distillation is conducted so that about 30 cc. pass over in about 10 minutes, and when 360 cc. have distilled it is discontinued. To the distillate is

a Ber. d. deu. Chem. Ges.: *24*, 3583. *b* Landw. Versuch-Stat.: *42*, 381. *c* Chem. Zeitung: *51*, 966.

added the volume of the solution of purified phloroglucinol described in an article which follows, which contains as much phloroglucinol as furfural expected. The mixture is stirred well and allowed to stand over night. The precipitate is then collected in a Gooch crucible, washed with 100 cc. of water, taking care not to allow it to suck dry enough for cracks to form during the washing, and the suction pump allowed to run 30 minutes after the washing is completed. It is then dried to constant weight at 100 degrees which requires from 7 to 9 hours.

For convenience in calculation, a table has been constructed showing the per cent of pentosan when three grams of substance is used. (Table IV.) It is based on the formula:

Phloroglucid (less than and up to 0.2 gram) ÷ 1.82 = furfural.
Phloroglucid (from 0.2 to 0.3 gram) ÷ 1.895 = furfural.
Phloroglucid (from 0.3 to 0.4 gram) ÷ 1.92 furfural.
Phloroglucid (above 0 4 gram) ÷ 1.93 = furfural.
Furfural—0 0104 + 1.88 = pentosan.

Values of phloroglucid less than .01 gram are not given. The interpolation can be made by dividing the weight of phloroglucid in excess of hundreths of grams by 3, and adding to the percentage given in the table.

VOLUME OF DISTILLATE.

Substances which form a precipitate with phloroglucinol continue to distill beyond 360 cc., which volume, however, is the one chosen. For example, with two samples of hay, 360 cc., then 120 cc., then 120 cc., were distilled, and the last distillates still gave a small precipitate with phloroglucinol. With bran (1491) and timothy hay (816), the furfural was determined in a second 360 cc.; bran gave 0.0040 gram phloroglucid, equivalent to 0.13 per cent pentosan if it were added to the first precipitate, and the hay 0.0126 gram or 0.42 per cent pentosan.

It is generally believed that all the furfural distils in the first 400 cc., aniline acetate being used as a test. Flint and Tollens(*a*) assume that 400 cc. is the largest quantity that will be distilled in ordinary samples. Quite possibly the compound which distills above 400 cc. is not furfural, but some other compound.

DIGESTIBILITY OF PENTOSANS.

In this country, comparatively few experiments on the digestibility of pentosans are on record. W. E. Stone(*b*) determined their digestibility in certain feeding stuffs, as follows:

a Landw. Versuch-Station, *42*. 398. *b* Agr. Science: 7, 6; Maine Station Report: 1893, 44.

TABLE IV.—*Calculation of Pentosans.*

Wt. Ppt.	Wt. Pentosan.	Per Cent Pentosan.	Wt. Ppt.	Wt. Pentosan.	Per Cent Pentosan.	Wt. Ppt.	Wt. Pentosan.	Per Cent Pentosan.	Wt. Ppt.	Wt. Pentosan.	Per Cent Pentosan.
			.21	.1883	6.29	.41	.3799	12.66	.61	.5747	19.16
			.22	.1987	6.62	.42	.3896	12.99	.62	.5844	19.48
.03	.0115	.38	.23	.2086	6.95	.43	3994	13.31	.63	.5942	19.81
.04	.0218	.73	.24	.2185	7.28	.44	.4091	13.64	.64	.6039	20.13
.05	.0322	1.07	.25	.2285	7.62	.45	.4188	13.96	.65	.6137	20.46
.06	.0425	1.42	.26	.2384	7.95	.46	.4285	14.28	.66	.6235	20.78
.07	.0529	1.76	.27	.2483	8.28	.47	.4383	14.61	.67	.6332	21.11
.08	.0633	2.11	.28	.2583	8.61	.48	.4480	14.93	.68	.6430	21.43
.09	.0736	2.45	.29	.2681	8.94	.49	.4577	15.26	.69	.6528	21.76
.10	.0840	2.80	.30	.2741	9.14	.50	.4675	15.58	.70	.6626	22.09
.11	.0943	3.14	.31	.2839	9.45	.51	.4772	15.91	.71	6723	22.41
.12	.1047	3.49	.32	.2937	9.79	.52	.4870	16.23	.72	.6820	22.73
.13	.1151	3.84	.33	.3035	10.12	.53	.4967	16.56	.73	.6917	23.06
.14	1254	4.18	.34	.3133	10.44	.54	.5065	16.88	.74	.7014	23.38
.15	.1357	4.52	.35	.3231	10.77	.55	.5162	17.21	.75	.7111	23.70
.16	.1457	4.85	.36	.3329	11.10	.56	.5260	17.53	.76	.7208	24.03
.17	.1560	5.20	.37	.3427	11.42	.57	.5358	17.86	.77	.7305	24.35
.18	.1664	5.55	.38	.3525	11.75	.58	.5455	18.18	.78	.7403	24.67
.19	.1767	5.89	.39	.3623	12.08	59	.5552	18.51	.79	.7500	25.00
.20	.1870	6.23	.40	.3702	12.34	.60	.5650	18.83	.80	.7597	25.32

	Per Cent of Pentosans Digested.
Timothy hay—early bloom	60.4
Timothy hay—early bloom	54.6
Timothy hay—late cut	62.8
Timothy hay—late cut	48.2
Timothy hay	48.0
Timothy hay	49.5
Danthonia spicata	68.6
Agrostis vulgaris	70.0
Calamagrastis canadensis	90.4
Triticum repens	59.9
Hungarian grass	68.2
Trifolium hybridum	56.8
Corn fodder, Northern corn	76.6
Corn fodder, Southern corn	69.6
Timothy hay and sugar beets	71.3
Timothy hay and rutabagas	57.1
Timothy hay and wheat bran	45.6
Timothy hay and glutin meal	59.1
Agrostis vulgaris hay and wheat bran	54.1
Agrostis vulgaris hay and wheat middlings	64.9

The pentosans were determined by titrating the distillate with a standard solution of phenylhydrazine, using Fehling's solution as an indicator.

Excluding Calamagrostic canadensis, the average digestibility of the pentosans in the 19 substances, is 60.3 per cent. Stone draws the following conclusions: "While these bodies are at present classified among the carbohydrates, they are really much less digestible and hence of less food value, than the better known members of this group, as starch, sugar, etc. In many cases the indicated digestibility is even less than that assigned to the fiber of the same materials, and the average of all the experiments is but little higher than the corresponding average for the fiber. Indeed, from the data at hand it would appear that of all the food constituents capable of individual estimation, these are among the less soluble in the digestive fluids, although commonly included among those substances which are regarded as in a high degree digestible."

J. B. Lindsay and E. B. Holland* have determined the digestibility of the pentosans in the following materials, using the method of weighing the phenylhydrazine precipitate:

* Agricultural Science, *8*, 172.

	Per Cent of Pentosans Digested.
Hay of mixed grasses (a)	63
Hay of mixed grasses (b)	62
Buffalo gluten feed	78
New process linseed meal	89
Old process linseed meal	84
Corn cobs	62
Dried brewers' grains	55
Spring wheat bran	62
Winter wheat bran	64

The average coefficient is 68.8 in the above table.

In six out of nine cases, they state, the pentosans are practically as digestible as any other of the groups of fodder substances. "With the more concentrated foods it will be observed that the pentosans are as digestible as either the fat, protein, or extract matter. *The results make clear that association has a great deal to do with digestibility.* In the hays, corn cobs, and brewers' grain, where the woody substance (lignin) is present to a considerable extent, the digestibility of the pentosans is noticeably less than when the incrusting substance is absent. Whether or no the pentosans are chemically united to the incrusting substance is not known, but it is not at all improbable."

H. C. Sherman (Jour, Am. Chem. Soc. 19, 308) found the digestibility of true pentosans to be 66.2 per cent in wheat bran.

Determinations of total pentosans have been made in the feeding stuffs, wastes, and excrements which were used in determining the digestibility of the nitrogen-free extract less sugars. The determinations were in duplicate, by the method already described. The complete composition of the excrements, wastes, and feeding stuffs is tabulated in Table V. The digestibility of the pentosans are worked out in Tables X—XVII, in the back of this bulletin. In Table VI is a comparison of the digestibility of total pentosans and of the other fodder groups. The figures for fats, protein, nitrogen-free extract are worked out in Bulletins 140 and 160 of this Station.

There is no regularity in the relation of the digestibility of the total pentosans to the other fodder groups visible in this table. The pentosans in green rape have a very high coefficient, those in cowpea meal and corn bran come next, and the hays and rice bran are last in order.

The average digestibility of the pentosans in the feeding stuffs tabulated in Table VI is 68.5 per cent. The average for all the materials (34) cited in this paper is 64.2 per cent. The average for the pentosans in the timothy hay (8 samples) is 53.9.

TABLE V.—*Composition of Feeding Stuffs, Wastes and Excrements on Dry Matter.*

Old No.	New No.		Sugars.	Total Pentosans.	True Pentosans.	Pseudo-Pentosans.	Residual N-free Ext.
656	1452	Timothy hay No. I	8.33	24 86	19.71	5.15	16.88
753	1455	Crabgrass hay No. I	1.89	26 25	21.90	4.35	21.40
754	1456	Crabgrass hay No. II	2 20	24.71	19 85	4.85	24 09
759	1461	Cowpea meal	5.66	6.83	6 83	0	52.20
812	1480	Corn bran	2.93	25 15	25.15	0	41.36
819	1463	Green rape No. I	8.41	10.57	9.57	1.00	29 81
820	1485	Green rape No. II	7 03	8.71	8 04	0.67	26 04
917	1490	Rice bran	1.56	10.88	9 88	1.00	40.31
1412	1474	Timothy hay No. II	5 30	26 29	20 91	5.38	-------
*1418	1476	Timothy hay No. III	8 56	23 52	-------	-------	-------
*1359	--	Corn silage No. I	1.87	22 71	-------	-------	-------
*1378	1469	Corn silage No. II	2 39	20.68	-------	-------	-------
*1414	1475	Cotton-seed meal	7.94	7.83	-------	-------	-------
661	1453	Excrement	0	24.24	18.31	5.93	-------
663	1454	Waste	(1)	22.22	16 87	5.35	-------
755	1457	Excrement	0	25.77	20 96	4 81	-------
756	1458	Waste	-------	25 06	21 21	3.85	-------
757	1459	Excrement	-------	20 79	17 84	2.95	-------
758	1460	Excrement	-------	22 36	18.78	3 58	-------
762	1479	Excrement	-------	18.54	15 20	3 34	-------
763	1462	Excrement	-------	18.31	16.01	2.30	-------
813	1481	Waste	-------	21.64	21.64	0	-------
815	1482	Excrement	-------	23.73	21.46	2.27	-------
817	1483	Waste	-------	20 77	20 77	0	-------
818	1484	Excrement	0	24 55	22 56	1.99	-------
910	1486	Excrement	0	3.84	2.99	0 85	-------
911	1487	Excrement	0	3 61	2.76	0.85	-------
912	1465	Excrement	0	4.78	3 46	1.32	-------
913	1466	Excrement	0	5.11	3.74	1.37	-------
914	1488	Excrement	0	17 48	14.85	2.63	-------
915	1489	Excrement	0	19.31	16.13	3 18	-------
1410	1472	Excrement	0	23.81	18.61	5 20	-------
1411	1473	Excrement	0	23.78	18.38	5.40	-------

* Not digested.

(1) Wastes *assumed* to contain same per cent sugars as feeding stuffs. Wastes not in table assumed to have same composition as feeding stuffs.

TABLE VI.

	Ether Extract.	Protein.	N free Extract.	Crude Fiber.	Pentosans.
Timothy hay No. I	22	34	60	52	56
Timothy hay No. II	42	21	56	54	56
Green rape (early) No. I	54	90	94	90	95
Green rape (later) No. II	43	89	90	84	92
Crabgrass hay No. I	36	32	50	67	63
Crabgrass hay No. II and cowpea meal	55	71	77	64	66
Cowpea meal	74	82	95	39	76
Crabgrass hay No. I and corn bran	69	49	75	60	69
Corn bran	72	54	80	51	72
Crabgrass hay No. I and rice bran	82	52	66	56	60
Rice bran	89	63	80	19	54

DISTRIBUTION AND DIGESTIBILITY OF PENTOSANS.

A rough division of the total pentosans has already been made: those contained in the nitrogen-free extract, and those in the crude fiber. The latter consist of oxycelluloses and lignocelluloses; the former are perhaps for the most part made up of pentosans, but contain oxycelluloses and lignocelluloses, since these too are sometimes soluble in the acid or alkali.

These two groups of bodies possess different coefficients of digestibility, as will be seen.

The total pentosans less those in the crude fiber, gives the pentosans in the nitrogen-free extract. The crude fiber was prepared according to the methods of analysis of the Association of Official Agricultural Chemists, using, however, 3 grams material, and 300 cc. of caustic soda and of sulphuric acid instead of 2 grams and 200 cc. The last filtration was made on asbestos, the fiber transferred to a side-neck distilling flask, and pentosans in it determined as already described. The asbestos gave rise to severe bumping, which moderated when broken glass was added.

The composition of the hays, etc., is tabulated in Table V. The digestibility of the constituents is worked out in Tables X—XVII. In Table VII is tabulated the mean figures for the distribution and digestibility of the pentosans. From 78 to 100 per cent of the total pentosans are contained in the nitrogen-free extract. Corn bran and cowpea meal contain no pseudo-pentosans, so the digestibility of the pseudo-pentosans in the rations in which they were fed may be compared directly with their digestibility in the crabgrass hay fed alone. These figures are: Crabgrass hay alone, 69.9 per cent pseudo-pentosans digested; with corn bran, 46.3 per cent; with rice bran 60.3.

The results for crabgrass hay alone are plainly anomalous.

In all cases save one, the pseudo-pentosans are less digestible than the pentosans in the nitrogen-free extract. The difference is not, as a rule, as great as might be expected. The hays contain about 20 per cent of their pentosan in the crude fiber; in timothy hay, the pseudo-pentosans (lignin, oxycellulose) are digested on the average, 14 per cent less than the true pentosans; the same is true of green rape.

TABLE VII.—*Distribution and Digestibility of Pentosans.*

		OF 100 PARTS TOTAL PENTOSAN.		DIGESTIBILITY.			
		True Pent.	Pseudo Pent.	Of Total.	(b) Of True.	(b) Of Pseudo Pent.	True—Pseudo (a-b.)
656	Timothy hay No. I	79.3	20 7	55 8	58.1	46 9	11.2
1412	Timothy hay No. II	79 5	20.5	55.9	57.0	52.0	5.0
753	Crabgrass hay No. I	81.6	18 4	63 1	61.0	69 9	—8.8
754	Crabgrass hay No. II	80.4	19.6	------	------	------	------
759	Cowpea meal (1)	100	0	76.1	76.1	------	------
812	Corn bran (1)	100	0	71.6	71.6	--	------
819	Green rape No. I	90 5	9.5	94.6	95 7	84.6	11.1
820	Green rape No. II	92.3	7.7	91.9	93.2	75.9	17.3
917	Rice bran (1)	90.8	9.2	53.5	57 3	------	------
	Rations:						
------	Crabgrass hay No. II and cowpea meal	------	------	65 9	66.5	62 5	4.0
------	Crabgrass hay No. I and corn bran	------	------	69.2	70.4	46.3	24.1
------	Crabgrass hay No. I and rice bran	------	------	60.4	60.4	60 3	0.1

(1) Digestibility calculated from rations below.

COMPOSITION AND DIGESTIBILITY OF NITROGEN-FREE EXTRACT.

The nitrogen-free extract has been divided into the three groups: Sugars, pentosans, and residue, in these experiments. The composition and digestibility of the nitrogen-free extract is exhibited in Table VIII. In the hays and in green rape, the pentosans are more digestible than the residue, coming next to the sugars. In the cowpea meal, corn bran, and rice bran, the residue is digested to a greater extent than the pentosans, but this residue consists for the most part of starch, so that we may say that starch is more digestible than pentosans; and that the starch of cowpea meal must be 97.4 per cent digested, of corn bran 86.1 per cent, of rice bran 85. per cent, at the

least. The components of the nitrogen-free extract may therefore be arranged in the following order, according to their digestibility: (1) sugars, (2) starch, (3) pentosans, (4) residue.

TABLE VIII.—*Composition and Digestibility of Nitrogen free Extract.*

		IN 100 PARTS.			DIGESTIBILITY.		
		Sugars.	Pentosans.	Residue.		Pentosans.	Residue.
656	Timothy hay No. I	14.9	35.2	49.9	Sugars 100 per cent.	58.1	50.1
1412	Timothy hay No. II	10.5	41.6	47.9		57.0	46.0
753	Crabgrass hay No. I	4.2	48.4	47.4		61.0	32.7
754	Crabgrass hay No. II	4.8	43.0	52.2		----	----
759	Cowpea meal	4.8	10.6	84 6		76.1	97.4
812	Corn bran	4 2	36 2	59.6		71.6	86.1
819	Green rape No. I	15.2	20.6	64.2		95.7	91.4
820	Green rape No. II	19 8	18.9	61.3		93.2	86.5
917	Rice bran	3.0	19.1	77.9		57.3	85.0

COMPOSITION AND DIGESTIBILITY OF CRUDE FIBER.

Crude fiber may be divided into two groups: Pseudo-pentosans, and residual crude fiber. The composition and digestibility of the crude fiber is exhibited in Table IX. The pseudo-pentosans are, with one exception, less digestible than the crude fiber, the difference between the coefficients of digestion of pseudo-pentosans and residual

TABLE IX.—*Composition and Digestibility of Crude Fiber.*

		100 PARTS CRUDE FIBER CONTAINS		DIGESTIBILITY OF			Residual N-free Extract.
		Pseudo Pentosans.	Residue.	Total Crude Fiber.	Pseudo Pentosans.	Residue Crude Fiber.	
656	Timothy hay No. I	9 2	90.8	52.3	46.9	53.3	50.1
1412	Timothy hay No. II	14.4	85.6	53.8	52.0	54.1	46.0
753	Crabgrass hay No. I	13.0	87.0	67.3	69.9	67.0	32.7
754	Crabgrass hay No. II	13.4	86.6	------	------	------	------
759	Cowpea meal	0	100	39.2	......	39 2	97.4
812	Corn bran	0	100	50 8	..	50.8	86.1
819	Green rape No. I	7.7	92 3	90 0	84.6	90.4	91.4
820	Green rape No. II	6.3	93.7	84.0	75.9	84.6	81.5
917	Rice bran	8.3	91.7	19.1	......	19.1	85.0

crude fiber being, for timothy hay No. I, 6.4; No. II, 2.1; green rape No. I, 5.8; No. II, 8.7; crabgrass hay, 2.9.

Since crude fiber consists of oxycelluloses, lignocelluloses, and cellulose, and the "pseudo-pentosans" are in the two former, this means that the cellulose is more digestible, which agrees with experiments which prove that the portion of the crude fiber digested has very nearly the composition of cellulose.

The residual crude fiber is more digestible than the nitrogen-free extract in the timothy hay and crabgrass hay, and slightly less so in the green rape, and very much less in the cowpea meal, corn bran, and rice bran. The residual nitrogen-free extract of the last three substances is composed for the most part of starch.

DIGESTIBILITY OF CRUDE FIBER.

The crude fiber of hays is often found to have as great, or a greater, apparent coefficient of digestion as the nitrogen-free extract. If we subtract the sugar and pentosans from the nitrogen-free extract of the hays, the residue is 4.4 per cent (timothy hay No. 1), 12 per cent (timothy hay No. 2) and 47 per cent (crabgrass hay No. 1) less digested than the crude fiber.

It is assumed, in digestion experiments, that those fodder groups which are not digested, pass through unchanged, an assumption which must be modified for the nitrogenous matters and the ether extract, since products of metabolism appear in the excrement which fall into these groups. It is quite possible that the crude fiber undergoes a change in the intestines which renders it soluble in acids or alkalies, and therefore a portion of the nitrogen-free extract, thus making the digestibility of the crude fiber greater than it should be, and of the nitrogen-free extract less so. Crude fiber fed to an animal may disappear in several ways:

(1) By formation of soluble compounds, and resorbtion.

(2) By complete decomposition to carbon dioxide and marsh gas.

(3) By decomposition with the formation of soluble products, which are resorbed, and carbon dioxide or marsh gas.

(4) By decomposition with formation of products which are not resorbed and are soluble in hot alkali or acids.

The disappearance of crude fiber in digestion is generally believed to be due to the action of bacteria, the crude fiber being converted to gases, or to gases and soluble products and resorbed. According to the experiments of G. Kuhn, for every 100 parts of cellulose and nitrogen-free extract digested by steers, 4.5 parts, or 1-7 of the carbon, appears as marsh gas. The nitrogen-free extract takes part in this action as well as the crude fiber.

Besides the sugars, starches, gums, etc., the nitrogen-free extract of hays is composed of the less resistant portions of the cell walls, partly made up of pentosans. The crude fiber is the older, and more resistant portion of the cell walls, so that our digestion experiments seem to show that the older and more resistant cellular structures are in many cases digested to a greater extent than the younger and less resistant. To avoid this difficulty, it has been assumed that the more resistant portions are converted by bacteria into gases, or gases and soluble products which are resorbed. This may be, in part, true, but it can not be all the truth; since, according to Kuhn, the nitrogen-free extract takes part in the formation of gases, and we would naturally suppose them to be attacked first, unless, like starch and sugar, they are quickly rendered soluble and digested. With this hypothesis, the nitrogen-free extract should still be digested to a greater extent. The explanation appears to be that the nitrogen-free extract is more digested than the crude fiber; that the crude fiber and undigested nitrogen-free extract, remaining several days in the intestines, under favorable conditions for the action of bacteria, are decomposed, with formation of gases, of soluble products which are resolved, and of insoluble products (humus-like substances) which pass into the excrement, and, being soluble in alkalies or acids, are classed with the nitrogen-free extractives. Action like this would lower the digestibility of the nitrogen-free extract, and raise that of the crude fiber. If we could determine the digestibility of the constituents of the nitrogen-free extract one by one by a method which would not include the decomposition products of the crude fiber, if the hypothesis above stated is true, there would be a portion of the "nitrogen-free extract" in the excrement which would come from the crude fiber, and not be undigested portions of the nitrogen-free extract.

ANALYSIS OF FEEDING STUFFS.

The ash, nitrogenous matters, and ether extract are here left out of consideration. E. Schulze* has proposed that in addition to the determination of crude fiber, the non-nitrogenous matters insoluble in ether, alcohol, water, and diastase solution be determined. Fats, lecithin, starch, soluble carbohydrates, amides, soluble proteids, etc., would go in solution, and the residue would consist essentially of the material of cell walls, insoluble proteids, and a portion of the ash. It is corrected for the proteids and ash, and the crude fiber subtracted. Thus a division is made between the soluble and easily digestible nitrogen-free extract and the insoluble carbohydrates.

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* **Landw. Versuch-Stationen, *49*, 434.**

Where time is not available to determine sugars, starch, and pentosans, the above suggestion of E. Schulze should be adopted, even if the determination of crude fiber has to be left out altogether. The digestibility of the crude fiber does not differ, in the case of hays, greatly from that of the nitrogen-free extract.

The work which has been described in these pages shows that the nitrogen-free matters may be arranged in the following general order, according to their digestibility: (1) sugar, (2) starch, (3) true pentosans, (4) crude fiber, (5) residual nitrogen-free extract, (6) pseudo-pentosans. The determination of sugar and total pentosans is more important in coarse feeding stuffs than that of crude fiber; and of sugar, starch, and pentosans more important than of crude fiber in concentrated feeding stuffs. In digestion experiments, it would be better to determine sugar, starch, and pentosans in the feeding stuffs and excrements directly, than to follow the suggestion of E. Schulze, and determine the ether-alcohol-water-diastase insoluble portions. The latter, in the case of excrements, would include any of the nitrogen-free extract or crude fiber rendered water soluble by fermentation or other action in the animal, which would be excluded by the former method.

SUMMARY.

(1) Sugars are found in all feeding stuffs, sometimes in large percentages are completely digested, and their determination is of importance in the case of hays and cotton-seed meal.

(2) Subtraction of sugars from the nitrogen-free extract of hays reduces its digestibility appreciably. With concentrated feeding stuffs the reduction is slight.

(3) The average digestibility of total pentosans in 36 samples is 64.2. The average for timothy hay (8 samples), is 53.9.

(4) The total pentosans are distributed between the nitrogen-free extract and the crude fiber. The former are here called true pentosans, the latter pseudo-pentosans.

(5) The true pentosans have a higher coefficient of digestibility than the pseudo-pentosans. They form from 79.3 to 100 per cent of the total pentosans.

(6) True pentosans and sugars make up from 22 to 52.6 per cent of the nitrogen-free extract.

(7) The constituents of the nitrogen-free extract can be arranged in the following order according to their digestibility: (1) sugar, (2) starch, (3) pentosans, (4) remainder.

(8) Crude fiber may be divided into pseudo-pentosans and residue. The pseudo-pentosans make up from 0 to 14.4 per cent of the crude fiber, and are less digestible, as a rule.

(9) Crude fiber of coarse feeding stuffs is often digested to a greater extent than nitrogen-free extract. This may be due to decomposition of crude fiber into substances soluble in alkalies and acids, which pass into the excrement, and hence make the digestibility of crude fiber appear greater, of the nitrogen-free extract less than it really is.

(10) It is more important to determine carbohydrates soluble in ether, alcohol, water, and diastase solution, as suggested by E. Schulze, than to determine crude fiber, when conclusions as to the quality of feeding stuff is the object.

(11) The determinations of sugars, starch, and total pentosans are more important than that of crude fiber, especially in digestion experiments.

Purification of Phloroglucinol.

G. S. FRAPS, PH. D., Assistant Chemist.

The methods of analysis adopted by the Association of Official Agricultural Chemists require the use of a phloroglucinol free from diresorcinol in the determination of pentosans. According to Kruger and Tollen(*a*), small quantities of diresorcinol do not affect the accuracy of the determination; Councler(*b*) found Merck's phloroglucinol purissimum to contain from 7.5 to 14.6 per cent of diresorcinol, and concludes that it varies greatly in composition, and often contains enough diresorcinol to vitiate the results. Councler believes that it is better to add the phloroglucinol in the solid form, in order to keep the volume of the liquid as small as possible.

If the phloroglucinol is added in the solid form, only that free from diresorcinol can be used, as the latter compound is soluble only with difficulty in hydrochloric acid of 1.06 specific gravity. Phloroglucinol can be purified by dissolving it in hydrochloric acid of 1.06 specific gravity, and allowing the diresorcinol to crystallize out. The phloroglucinol remaining in solution is sufficiently pure to give the same results as Merck's phloroglucinol free from diresorcinol.

The method of purification is as follows: About 300 cc. hydrochloric acid 1.06 sp. gr., is heated in a beaker, 11 grams commercial phloroglucinol added, with stirring, and the heating continued until it has almost all dissolved. Some impurities resist solution, and they may be disregarded. Pour the hot solution into sufficient of the same hydrochloric acid to make the volume 1,500 cc. Let stand at least one night (better several days), to allow the diresorcinol to crystallize out, and filter immediately before using. The solution may turn yellow, but this does not interfere with its usefulness. One hundred cc. of hydrochloric acid 1.06 sp. gr., dissolves 0.7 gram of pure phloroglucinol.

A comparison of the phloroglucinol solution above described with the phloroglucinol free from diresorcinol of Merck, shows them to give the same results. For example, on three solutions of furfural, the weights of precipitates were, using phloroglucinol:

	I	II	III
(*a*) Purified as above	0.4575 gram.	0.5115	0.4647
(*b*) Merck's free from diresorcinol	0.4620	0.5124	0.4671

which is as close as might be expected.

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a Zeits. Angew. Chem. 1896, 40. *b* Chem. Zeit. *21*, 2; Analyst *22*, 106.

TABLE X.—**Nutrients Consumed and Excreted, with Percentages Digested.*

SHEEP NO. 1.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen free Extract.	N Free Extract less Sugars.	Total Pentosans.	Pentosans in N-Free Extract.	N-Free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans in it.	Pentosans left by 2.22 per cent Acid.
656	Timothy hay No. 1 fed	11102.1	924.8	6108.3	......	2760.0	....	......	3602.6	571.8	......	167.6
663	Waste hay	1231.8	102.7	6 3 1	..	273.7	......	.....	407.2	65.9	..	25.7
	Consumed	9870.3	822.1	5555.2	4733.1	2486.3	1980.4	2752.7	3195.4	505.9	2689.5	141.9
661	Excrement	4528.4	0	2203.1	2203.1	1097.7	829.2	1373.9	1524.3	268.5	1255.8	92.4
	Digested	......	822.1	3352.1	2530.0	1388.6	1151.2	1378.8	1671.1	237.4	1433.7	49.5
	Per cent digested	.....	100	60.3	53.5	55.8	58.1	50.1	52.3	46.9	53.3	34.2

*See Table II, Bulletin 148.

TABLE XI.—*Nutrients Consumed and Excreted in Grams, with Percentages Digested.*

SHEEP NO. 3.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen-free Extract.	N Free Extract less Sugars.	Total Pentosans.	Pentosans in N-Free Extract.	N Free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans in it.
753	Crab-grass hay No. I fed	8095.9	153.0	3658.5	......	2125.1	......	......	3007.6	391.0	......
755	Waste	2845.8	53.8	1361.4	......	733.4	......		1016.8	136.9	......
	Consumed	5250.1	99.2	2297.1	2197.9	1381.7	1127.6	1070.3	1990.8	254.1	1736.7
757	Excrement	2399.0	0	1195.4	1195.4	498.8	428.0	767.4	623.7	70.8	552.9
	Digested	2851.1	99.2	1101.7	1002.5	882.9	699.6	302.9	1367.1	183.3	1183.8
	Per cent digested	54.31	100	48.0	45.6	63.9	62.0	28.3	68.6	72.1	68.2

SHEEP NO. 4.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen-free Extract.	N Free Extract less Sugars.	Total Pentosans.	Pentosans in N-Free Extract.	N Free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans in it.
753	Crab-grass hay No. I fed	8095.9	153.0	3658.5	......	2125.1	......	......	3007.6	391.0	......
756	Waste	881.2	16.7	401.8	......	220.8	......	......	318.0	33.9	......
	Consumed	7214.7	136.3	3256.7	3120.4	1904.3	1547.2	1573.2	2689.6	357.1	2332.5
758	Excrement	3214.3	0	1584.0	1584.0	718.7	603.6	980.4	914.5	115.1	799.4
	Digested	4000.4	136.3	1672.7	1536.4	1185.6	943.6	592.8	1775.1	242.0	1533.1
	Per cent digested	55.5	100	51.4	49.3	62.2	60.0	37.1	66.0	67.8	65.7
	Mean per cent digested	......	100	49.7	47.5	63.1	61.0	32.7	67.3	69.9	67.0

*See Table II, Bulletin 160.

TABLE XII.—* *Nutrients Consumed and Excreted in Grams, with Percentages Digested.*

SHEEP NO. 3.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen-free Extract.	N Free Extract less Sugars.	Total Pentosans.	Pentosans in N Free Extract.	N Free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans in it.
754	Crab-grass hay No. II fed	4088 8	90 0	1887.0	-------	1010.3	1812.0	------	1482 2	198.3	--------
759	Cow-pea meal fed	3963 1	224.3	2561 4	...	270.7	270 7	------	107.2	0	--------
	Total fed	8051 9	314.3	4448 4	-----	1281.0	1082 7	------	1649.4	198 3	-------
760	Waste hay	317 0	7 0	149.6	-------	78.3	63.0	-------	109 8	15 3	-------
	Consumed	7734.9	307.3	4298.8	3991 5	1202 7	1019.7	2971 8	1539 6	183 0	1356.6
762	Excrement	2170.9	0	976.5	976.5	402.5	330.0	646.5	546 6	72 5	474.1
	Digested	5564 0	307.3	3322.3	3015.0	800.2	689.7	2325.3	993 0	110.5	882 5
	Digested from Crab-grass hay	2070.7	83 0	863 4	780.4	587.1	476.6	303.8	923.6	110.5	813 1
	Digested from cow pea meal	3493.3	224.3	2458.9	2234.6	213 1	213.1	2021.5	69.4	---	69.4
	Per cent ration digested	71.9	100	77.3	75.6	66.5	67.6	78.3	64.5	60 4	65 0
	Per cent cow-pea meal digested	88.0	100	96 0	95.6	78 7	78.7	97.8	41.5	------	41.5

*See Table III, Bulletin 160.

TABLE XII.—*Continued.*

SHEEP NO. 4.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen-free Extract.	N Free Extract less Sugars.	Total Pentosans.	Pentosans in N-Free Extract.	N Free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans in it.
754	Crab grass hay No. II fed	4088.8	90.0	1887.0	......	1010.3	......	......	1482.2	198.3	......
759	Cow-pea meal fed	3963.1	224.3	2561.4	......	270.7	......	2066.4	167.2	0	......
	Total fed	8051.9	314.3	4448.4	......	1281.0	1082.7	......	1649.4	198.3	......
761	Waste hay	23.5	.5	9.2	......	5.8	4.8	......	8.3	1.0	......
	Consumed	8028.4	313.8	4439.2	4125.4	1275.2	1077.9	3047.5	1641.1	197.3	1443.8
763	Excrement	2425.2	0	1075.3	1075.3	444.0	374.2	701.1	587.6	69.8	517.8
	Digested	5603.2	313.8	3363.9	3050.1	831.2	703.7	2346.4	1053.5	127.5	926.0
	Digested from crab grass hay	2231.8	85.5	935.5	846.0	632.6	505.1	340.9	991.9	127.5	864.4
	Digested from cow-pea meal	3371.4	224.3	2428.4	2204.1	198.6	198.6	2005.5	61.6	......	61.6
	Per cent ration digested	69.8	100	75.8	73.9	65.2	65.3	77.0	64.2	64.6	64.1
	Per cent cow-pea meal digested	851.7	100	94.8	94.3	73.4	73.4	97.0	36.9	......	36.9
	Mean per cent ration digested	70.9	100	76.6	74.8	65.9	66.5	77.7	64.4	62.5	64.6
	Mean per cent meal digested	86.7	100	95.4	95.0	76.1	76.1	97.4	39.2	......	39.2

TABLE XIII.—* *Nutrients Consumed and Excreted in Grams, with Percentages Digested.*

SHEEP NO. 3.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen-free Extract.	N-Free Extract less Sugars.	Total Pentosans.	Pentosans in N-Free Extract.	N-Free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans in it.
753	Crab-grass hay No. I fed	3035.6	57.4	1371.9	-------	796.8	------	-------	1127.8	146 6	-------
812	Corn bran fed	7080 7	209.5	4918.3	------	1780 8	-------	------	739 9	0	-------
	Total fed	1011.6	264 9	6290.2	------	2577.6	---	------	1867.7	146.6	--------
813	Waste bran	1126 8	33.0	727 0	-------	243.8	--------	--------	118 0	-------	-------
814	Waste hay	309.7	5.8	145 6	-------	81.3	--------	------	107 8	15 0	-------
	Consumed in crab-grass hay	2726 2	51.6	1226 3	1174.7	715.5	573.9	600 8	1020 0	131.6	888.4
	Consumed in corn bran	5953.9	174.5	4191 3	4016 8	1537.0	1537.0	2479 8	621 9	-- ----	621 9
	Total consumed	8680 1	226.1	5417 6	5191.5	2252.5	2120 9	3011.6	1641 9	131.6	1510.3
815	Excrement	2971.8	0	1463.3	1463.3	705.2	637.7	725 6	635 4	67.5	567.9
	Digested	5708 3	226 1	3957.3	3728 2	1547.3	1483 2	2346 0	1006.5	64 1	942 4
	Digested from crab grass hay	1496.7	51.6	609 5	557.9	451.4	387 3	170.6	686.5	64.9	622.4
	Digested from corn bran	4211.6	174.5	3344.8	3170 3	1095 9	1095 9	2175 4	320.0	-- ---	320 0
	Per cent ration digested	62.75	100	73.0	71.8	68 7	69.9	76 4	61.4	48.7	62.4
	Per cent corn bran digested	70.77	100	79.8	78.8	71.3	71.3	87.7	51.4	--------	51.4

*See Table IV, Bulletin 160.

TABLE XIII.—*Continued.*

SHEEP NO. 4.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen free Extract.	N-free Extract less Sugars.	Total Pentosans.	Pentosans in N-free Extract.	N-free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans in it.
753	Crabgrass hay No. I fed	3035.9	57.4	1371.9	......	796.8	......	......	1127.8	146.6	......
812	Corn bran fed	7080.7	207.5	4918.3	......	1780.8	......	......	739.9	0	......
	Total fed	10116.6	264.9	6290.2	......	2577.6	......	......	1867.7	146.6	......
817	Waste bran	1326.8	38.9	458.7	......	275.6	......	......	157.2	0	......
816	Waste hay	1158.5	21.9	558.0	......	240.4	......	......	392.8	56.0	......
	Consumed in hay	......	35.5	813.9	778.4	556.4	465.8	312.6	582.7	90.6	492.1
	Consumed in bran	......	168.6	4459.6	4291.0	1505.2	1505.2	2785.8	735.0	0	735.0
	Total consumed	7631.3	204.1	5273.5	5069.4	2061.6	1971.0	3098.4	317.7	90.6	1227.1
818	Excrement	2554.1	0	1263.0	1263.0	627.0	576.2	686.8	552.7	50.8	501.9
	Digested	4046.5	204.1	4010.5	3806.4	1434.0	1394.8	2411.6	765.0	39.8	725.2
	Digested from hay	1030.7	35.5	404.5	369.0	351.0	311.2	57.8	473.3	39.8	433.5
	Digested from bran	4046.5	168.6	3606.0	3437.4	1083.6	1083.6	2353.8	291.7	0	291.7
	Per cent ration digested	66.5	100.	76.1	75.1	69.6	70.8	77.8	58.1	43.9	60.0
	Per cent bran digested	70.3	100.	80.8	80.1	71.9	71.9	84.4	50.1	......	50.1
	Mean per cent for ration	......	100.	74.6	73.5	69.2	70.4	77.1	59.8	46.3	61.7
	Mean per cent for bran	......	100.	80.3	79.5	71.6	71.6	86.1	50.8	......	50.8

TABLE XIV.—**Nutrients Consumed and Excreted in Grams, with Percentages Digested.*

SHEEP No. 3.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen-free Extract.	N-free Extract, less Sugars.	Total Pentosans.	Pentosans in N free Extract.	N-free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans in it.
819	Green rape No. I fed	7543.2	634.4	3500.8	......	797.2	......	......	985 1	75 4	......
824	Waste rape	12.	1.0	6.6	......	1.2	......	......	2.1	.1	......
	Consumed	7531.2	633.4	3494.2	2860 8	796.0	720.7	2140 1	983.0	75.3	907.7
913	Solid excrement	871 8	0	222.1	222 1	44.5	32.6	189 5	102.2	11.9	90 3
	Digested	6659 4	633.4	3272 1	2638 7	751 5	688 1	1950 6	880.8	63 4	817.4
	Per cent digested	88.4	100.0	93.6	92.2	94.4	95.5	91.1	89.6	84.2	90.0

SHEEP No. 4.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen-free Extract.	N-free Extract, less Sugars.	Total Pentosans.	Pentosans in N free Extract.	N-free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans in it.
819	Green rape No. I fed	7543.2	633.4	3500.8	......	797.2	......	......	985.1	75 4	......
823	Waste rape	78.2	6.2	24 5	......	8 0	......	......	10 5	.8	......
	Consumed	7465.0	627.2	3476.3	2849.1	789 2	714.6	2134 5	974.6	74 6	900.0
912	Excrement	852.2	0	208.3	208 3	40.7	29.5	178.8	93 8	11.2	82.6
	Digested	6612 8	627.2	3268 0	2640 8	748.5	685.1	1955 7	880 8	63 4	817.4
	Per cent digested	88 6	100 0	94 0	92.7	94 8	95 9	91.6	90.4	84.9	90 8
	Mean per cent digested	88.5	100.0	93.8	92.5	94 6	95.7	91.4	90 0	84.6	90.4

* (See Table No. V, Bulletin 160.)

TABLE XIV.—*Continued.*

SHEEP NO. 1.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen free Extract.	N-Free Extract less Sugars.	Total Pentosans.	Pentosans in N-Free Extract.	N-Free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans ie it.
820	Green rape No. II fed	9893.0	695.5	4213.4	......	861.7	....	......	1043.7	66.3	....
822	Waste rape	225.6	15.9	64.6	..	19.7	...	......	25.7	1.5	...
	Consumed	9667.4	679.6	4148.8	3469.2	842.0	777.2	2692.0	1018.0	64.8	953.2
910	Excrement	1774.3	0	388.4	388.4	68.1	53.0	335.4	165.9	15.1	150.8
	Digested	7893.1	679.6	3760.4	3080.8	773.9	724.2	2356.6	852.1	49.7	802.4
	Per cent digested	87.7	100	90.6	88.8	91.8	93.2	87.5	83.7	76.7	84.2

SHEEP NO. 2.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen free Extract.	N-Free Extract less Sugars.	Total Pentosans.	Pentosans in N-Free Extract.	N-Free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans ie it.
820	Green rape No. II fed	9893.0	695.5	4213.4	......	861.7	......	......	1043.7	66.3	......
821	Waste rape	368.4	25.9	123.5	...	32.1	......	......	52.2	2.5	......
	Consumed	9524.6	669.6	4089.9	3420.3	829.6	765.8	2654.5	991.5	63.8	927.7
911	Excrement	1866.3	0	444.1	444.4	67.4	51.5	392.9	156.4	15.9	140.5
	Digested	7658.3	669.6	3645.5	2975.9	762.2	714.3	2267.6	835.1	47.9	787.2
	Per cent digested	80.4	100	89.2	87.0	91.9	93.2	85.5	84.2	75.1	84.9
	Mean per cent digested	81.0	100	89.2	87.9	91.9	93.2	86.5	84.0	75.9	84.6

TABLE XV.—*Nutrients Consumed and Excreted in Grams, with Percentages Digested.*

SHEEP NO. 1.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen-free Extract.	N-free Extract, less Sugars.	Total Pentosans.	Pentosans in N free Extract.	N free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans in it.
753	Crabgrass hay No. I fed	4049.7	76.5	1830.1	......	1063.0	......	......	......	195.6	......
917	Rice bran fed	4074.2	63.6	2108.4	......	443.3	......	......	......	40.7	......
918	Waste bran	912.7	14.2	471.5	......	99.3	......	......	......	9.1	......
919	Waste hay	525.0	9.9	264.2	......	137.8	......	......	......	25.3	......
	Consumed in hay	3524.7	66.6	1565.9	1499.3	925.2	754.9	744.4	1314.1	170.3	1173.8
	Consumed in bran	3161.5	49.4	1636.9	1587.5	344.0	312.4	1275.1	369.4	31.6	337.8
	Total consumed	6686.2	116.0	3202.8	3086.8	1269.2	1067.3	2019.5	1713.5	201.9	1511.6
	Solid excrement	2650.0	0	1070.3	1070.3	463.2	393.5	676.8	690.9	69.7	621.2
914	Digested	4063.2	116.0	2132.5	2016.5	806.0	673.8	1342.7	1022.6	132.2	890.4
	Digested from hay	......	66.6	778.3	711.7	583.8	464.6	247.1	904.6	119.2	785.4
	Digested from bran	......	49.4	1354.2	1304.8	222.2	209.2	1095.6	118.0	13.0	105.0
	Per cent ration digested	......	100.	66.6	65.3	63.5	63.1	66.5	59.7	65.5	58.9
	Per cent bran digested	......	100	82.7	82.2	64.5	66.9	85.9	32.0	41.1	31.1

(See Table No. V, Bulletin 160.)

TABLE XV.—*Continued.*

SHEEP NO. 2.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen-free Extract.	N-Free Extract less Sugars.	Total Pentosans.	Pentosans in N-Free Extract.	N-Free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans in it.
753	Crab grass hay No. I fed	4049.7	76.5	1830.1	1753.7	1063.0	867.4	886.2	1504.5	195.6	....
917	Rice bran fed	4074.2	63.6	2108.4	2044.8	443.3	403.6	1642.2	493.0	40.7	....
	Fed and consumed	4123.9	140.1	3938.5	3798.4	1506.3	1270.0	2528.4	1997.5	236.3	1761.2
915	Solid excrement	3332.9	0	1371.5	1371.5	643.6	537.6	833.9	950.2	106.0	844.2
	Digested	4791.0	140.1	2567.0	2426.9	862.7	732.4	1684.5	1047.3	130.3	817.0
	Digested from hay	2263.3	76.5	919.6	843.1	670.7	540.4	302.7	1012.5	136.7	875.8
	Digested from bran	2567.7	63.6	1647.4	1583.8	192.0	192.0	1381.8	34.8	......	....
	Per cent ration digested	59.0	100	65.2	63.9	57.3	57.7	66.6	52.4	55.1	46.3
	Per cent bran digested	63.0	100	78.1	77.5	43.3	47.7	84.1	7.1	......	....
	Mean per cent ration digested	59.7	100	65.9	64.6	60.4	60.4	66.6	55.8	60.3	52.6
	Mean per cent bran digested	64.7	100	80.4	79.9	53.5	57.3	85.0	19.1	......	....

TABLE XVI.—* *Nutrients Consumed and Excreted, with Percentages Digested.*

SHEEP NO. 3.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen-free Extract.	N-Free Extract less Sugars.	Total Pentosans.	Pentosans in N-Free Extract.	N-Free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans in it.
1412	Timothy hay No. II fed	4547.8	241.0	2283.1	......	1195.6	......	....	1700.3	244.7	....
1413	Waste hay	48.3	2.6	23.9	......	11.5	....	....	17.7	2.6	......
	Consumed	4499.5	239.4	2259.2	2019.8	1184.1	942.0	1077.8	1682.6	242.1	1440.5
1410	Solid excrement	2120.7	0	960.6	960.6	501.9	394.6	566.0	750.5	110.3	640.2
	Digested	2378.8	239.4	1298.6	1059.2	679.2	547.4	511.8	932.1	131.8	800.3
	Per cent digested	52.8	100	57.5	52.4	57.4	58.1	47.5	55.4	54.4	55.6

SHEEP NO. 4.

Number.		Total Dry Matter.	Total Sugars.	Nitrogen-free Extract.	N-Free Extract less Sugars.	Total Pentosans.	Pentosans in N-Free Extract.	N-Free Extract less Pentosans and Sugars in it.	Crude Fiber.	Pentosans in Crude Fiber.	Crude Fiber less Pentosans in it.
1412	Timothy hay No. II fed	4547.8	241.0	2283.1	......	1195.6	......	.....	1700.3	244.7	......
	Waste	4.5	.2	2.3	......	1.1	...	......	1.6	.2	....
	Consumed	4543.3	240.8	2280.8	2010.0	1194.5	950.0	1090.0	1698.7	244.5	1454.2
1411	Solid excrement	2285.3	0	1026.0	1026.0	543.5	420.1	605.9	812.7	123.4	689.3
	Digested	2258.0	240.8	1254.8	1014.0	651.2	529.9	484.1	886.0	121.1	764.9
	Per cent digested	49.7	100	55.0	49.7	54.4	55.8	44.4	52.2	49.5	52.6
	Mean per cent digested	51.3	100	56.2	51.1	55.9	57.0	46.0	53.8	52.0	54.1

* Details not yet published.